WHAT IS CLAIMED IS:

1. A method of controlling movement in a dynamic system which can be expressed in terms of both rigid and flexible modes, the method comprising the steps of:

generating a rigid body input for the dynamic system;

processing the rigid body input so as to produce a processed input which compensates for vibrations in the flexible mode of the system; and

applying the processed input to control the dynamic system.

2. A method according to Claim 1, wherein the generating step comprises (i) creating a model of the rigid mode of the dynamic system based on a modal analysis, and (ii) determining the rigid body input based on the modal analysis.

3. A method according to Claim 1, wherein the rigid body input corresponds to a fundamental limiting parameter of the system, the fundamental limiting parameter of the system comprising a first parameter of the system to enter into saturation.

4. A method according to Claim 3, wherein the processing step processes the rigid body input in accordance with a system vibration limiting constraint and a system sensitivity constraint.

5. A method according to Claim 4, wherein the system vibration limiting and sensitivity constraints reduce vibration during movement of a component of the dynamic system by less than 100%.

6. A method according to Claim 1, wherein the processing step processes the rigid body input in accordance with one or more constraints that are a function of a movement distance of a component of the dynamic system.

7. A method according to Claim 1, wherein the processing step processes the rigid body input in accordance with a system vibration limiting constraint only.

8. A method according to Claim 1, wherein the processing step shapes the rigid body input using a predetermined shaping function.

9. A method according to Claim 8, wherein the rigid body input includes both transient portions and a steady state portion; and

wherein only the transient portions of the rigid body input are shaped in accordance with the predetermined shaping function.

10. A method according to Claim 1, wherein the processing step processes the rigid body input by filtering the input using filters having zeros which are substantially near poles of the system.

11. A method according to Claim 1, wherein the processing step processes the rigid body input in accordance with at least one of constraints relating to system thermal limits, system current limits, and system duty cycle.

12. A method according to Claim 1, wherein the processing step processes the rigid body input by determining a movement distance of a component of the dynamic system and modifying the rigid body input based on the movement distance.

13. A method according to Claim 1, wherein the rigid body input comprises a Posicast input.

14. A method according to Claim 1, wherein the rigid body input comprises a symmetric input.

15. A method according to Claim 1, wherein the processing step processes the rigid body input in accordance with a symmetric constraint that varies as a function of at least one of time and position of a component of the dynamic system.

16. A method according to Claim 1, wherein the rigid body input comprises a voltage which has been controlled by controlling current.

17. A method according to any one of Claims 1 to 16, wherein the processing step comprises:

identifying system parameters in real-time; and

modifying the rigid body input in real-time in accordance with the system parameters identified in the identifying step.

18. A method according to Claim 2, wherein the determining step determines the rigid body input in accordance with an insensitivity constraint.

19. A method according to Claim 2, wherein the model of the system comprises a plurality of equations for the system; and

wherein an insensitivity constraint for a particular system parameter is added to the system by taking a derivative of a system equation with respect to the insensitivity constraint and setting the derivative equal to zero.

20. A method according to Claim 2, wherein the model of the system comprises a plurality of equations for the system; and

wherein an insensitivity constraint for a particular system parameter is added to the system by setting a series of constraints for different values of the system parameter so as to limit a variation in the system parameter.

21. A method according to Claim 2, wherein the rigid body input is determined in accordance with a feedback signal; and

wherein the method further comprises adding a quasi-static correction factor to the feedback signal, the quasi-static correction factor correcting for a deflection in the component during movement.

22. A method according to Claim 2, further comprising determining a center of mass of a component of the dynamic system;

wherein the rigid body input is determined in accordance with a feedback signal based on the center of mass of the component.

23. A method of determining plural switch times for a voltage input to a dynamic system having plural modes, the method comprising the steps of:

generating a model of the dynamic system based on a modal analysis of each of the plural modes;

determining a response of the dynamic system in terms of the modal analysis in the model;

determining an expression for a contribution of each of the plural modes to a final location of the system based on a corresponding response, the contribution of each mode of the system being based on switch times for the voltage input;

estimating values relating to the plural switch times; and

calculating approximations of the values relating to the plural switch times based on the estimated values using the expression for the contribution of each of the plural modes and the modal analysis in the model of the dynamic system.

24. A method according to Claim 23, further comprising the step of re-calculating approximations of the values based on a previous approximation the values.

25. A method according to Claim 24, wherein the re-calculating step is repeated a plurality of times, each time using a re-calculated approximation of the values as the previous approximation of the values.

26. A method according to Claim 23, further comprising the step of generating a table comprising plural switch times;

wherein the estimating step comprises estimating the values using the table.

27. A method according to Claim 23, further comprising the step of generating at least one curve corresponding to the plural switch times;

wherein the estimating step comprises estimating the values using the at least one curve.

28. A method according to Claim 23, wherein the dynamic system comprise a data storage device; and

wherein the voltage inputs comprise voltage inputs to the data storage device.

29. A method according to Claim 23, further comprising the step of performing input shaping on the voltage input after switch times therefor have been calculated.

30. A method according to Claim 23, wherein the estimating step is performed using a parameter estimator.

31. A method of reducing unwanted vibrations in a dynamic system, the method comprising the steps of:

determining whether greater than a predetermined level of vibrations will be excited by a system input; and

modifying the input to the dynamic system in a case that greater than the predetermined level of vibrations will be excited, where the input to the dynamic system is modified so as to reduce the level of vibrations in the system to less than the predetermined level of vibrations

32. A method according to Claim 31, wherein the modifying step comprises using at least one of an input shaper, an inverse shaper, and a filter in order to modify the input to the dynamic system.

33. An apparatus which controls a dynamic system that can be expressed in terms of both rigid and flexible modes, the apparatus comprising:

a memory which stores computer-executable process steps; and

a processor which executes the process steps stored in the memory so as (i) to generate a rigid body input for the dynamic system, (ii) to process the rigid body input so as to produce a processed input which compensates for vibrations in the flexible mode of the system, and (iii) to apply the processed input to control the dynamic system.

34. An apparatus according to Claim 33, wherein the processor generates the rigid body input by (i) creating a model of the rigid mode of the dynamic system based on a modal analysis of the system, and (ii) determining an input to the dynamic system based on the modal analysis,

35. An apparatus according to Claim 32, wherein the rigid body input comprises a fundamental limiting parameter of the system, the fundamental limiting parameter of the system corresponding to a first parameter in the system to enter into saturation.

36. An apparatus according to Claim 35, wherein the processor processes the rigid body input in accordance with a system vibration limiting constraint and a system sensitivity constraint.

37. An apparatus according to Claim 36, wherein the system vibration limiting and sensitivity constraints reduce vibration during movement of the component by less than 100%.

38. An apparatus according to Claim 33, wherein the processor processes the rigid body input in accordance with one or more constraints that are a function of a movement distance of a component of the dynamic system.

39. An apparatus according to Claim 33, wherein the processor processes the rigid body input in accordance with a system vibration limiting constraint only.

40. An apparatus according to Claim 33, wherein the processor shapes the rigid body input using a predetermined shaping function.

41. An apparatus according to Claim 40, wherein the rigid body input includes both transient portions and a steady state portion; and

wherein the processor shapes only the transient portions of the rigid body input in accordance with the predetermined shaping function.

42. An apparatus according to Claim 33, wherein the processor processes the rigid body input by filtering the input using filters having zeros which are substantially near poles of the system.

43. An apparatus according to Claim 33, wherein the processor processes the rigid body input in accordance with at least one of constraints relating to system thermal limits, system current limits, and system duty cycle.

44. An apparatus according to Claim 33, wherein the processor processes the rigid body input by determining a movement distance of a component of the dynamic system and modifying the input based on the movement distance.

45. An apparatus according to Claim 33, wherein the rigid body input comprises a Posicast input.

46. An apparatus according to Claim 33, wherein the rigid body input comprises a symmetric input.

47. An apparatus according to Claim 33, wherein the processor processes the rigid body input in accordance with a symmetric constraint that varies as a function of at least one of time and position of a component of the dynamic system.

48. An apparatus according to Claim 33, wherein the processor processes the rigid body input based on a voltage which has been controlled by controlling current.

49. An apparatus according to any one of Claims 33 to 48, wherein the processor processes the rigid body input by (i) identifying system parameters in real-time, and (ii) modifying the input in real-time in accordance with the system parameters identified by the processor.

50. An apparatus according to Claim 33, wherein the processor generates the rigid body input in accordance with an insensitivity constraint.

51. An apparatus according to Claim 50, wherein the model of the system comprises a plurality of equations for the system; and

wherein an insensitivity constraint for a particular system parameter is added to the system by taking a derivative of a system equation with

respect to the insensitivity constraint and setting the derivative equal to zero.

52. An apparatus according to Claim 50, wherein the model of the system comprises a plurality of equations for the system; and

wherein an insensitivity constraint for a particular system parameter is added to the system by setting a series of constraints for different values of the system parameter so as to limit a variation in the system parameter.

53. An apparatus according to Claim 33, wherein the processor generates the rigid body input in accordance with a feedback signal; and

wherein the processor adds a quasi-static correction factor to the feedback signal, the quasi-static correction factor correcting for a deflection in the component during movement.

54. An apparatus according to Claim 33, wherein the processor determines a center of mass of a component of the dynamic system; and

wherein the processor generates the rigid body input in accordance with a feedback signal based on the center of mass of the component.

55. An apparatus which determines plural switch times for a voltage input into a dynamic system having plural modes, the apparatus comprising:

a memory which stores computer-executable process steps; and

a processor which executes the process steps stored in the memory so as (i) to generate a model of the dynamic system in terms of a modal analysis each of the plural modes, (ii) to determine a response of the dynamic system in terms of the modal analysis in the model, (iii) to determine an expression for a contribution of each of the plural modes to a final location of the system based on a corresponding response, the contribution of each mode of the system being based on switch times for the voltage input, (iv)

to estimate values corresponding to the plural switch times, and (v) to calculate approximations of the values corresponding to the plural switch times based on the estimated values using the expression for the contribution of each of the plural modes and the modal analysis in the model of the dynamic system.

56. An apparatus according to Claim 55, wherein the processor re-calculates approximations of the values based on a previous approximation of the values.

57. An apparatus according to Claim 56, wherein the processor re-calculates approximations of the values a plurality of times, each time using a re-calculated approximation of the values as the previous approximation of the values.

58. An apparatus according to Claim 55, wherein the processor generates a table comprising plural switch times; and

wherein the processor estimates the values using the table.

59. An apparatus according to Claim 55, wherein the processor generates at least one curve corresponding to the plural switch times; and

wherein the processor estimates the values using the at least one curve.

60. An apparatus according to Claim 55, wherein the dynamic system comprises a data storage device; and

wherein the voltage inputs comprise voltage inputs to the data storage device.

61. An apparatus according to Claim 55, further comprising the step of performing input shaping on the voltage input after switch times therefor have been calculated.

62. An apparatus which reduces unwanted vibrations in a dynamic system, the apparatus comprising:

a memory which stores computer-executable process steps; and

a processor which executes the process steps stored in the memory so as (i) to determine whether greater than a predetermined level of vibrations will be excited by an input to the system, and (ii) to modify the input to the dynamic system in a case that greater than the predetermined level of vibrations will be excited, where the processor modifies the input to the dynamic system so as to reduce the level of vibrations in the system to less than the predetermined level of vibrations.

63. An apparatus according to Claim 62, wherein the processor modifies the input to the dynamic system using at least one of an input shaper, an inverse shaper, and a filter.

64. A method of controlling a dynamic system in accordance with an input that is a function of time so as to reduce unwanted vibrations in the system, the method comprising the steps of:

generating a model of the dynamic system, the model defining system position in terms of both time and a system input, and the model constraining the system in accordance with one or more constraints relating to the unwanted vibrations;

determining an input to the dynamic system which reduces the unwanted vibrations based on the model generated in the generating step; and

controlling the dynamic system in accordance with the input determined in the determining step.

65. A method according to Claim 64, wherein the model of the system comprises a partial fraction expansion of third order equations that define the system.

66. A method according to Claim 65, wherein the partial fraction expansion equations comprise:

$$Finalpos = \sum_{i=1}^{N} V_i \; A \; \Delta t$$

$$0 = \sum_{i=1}^{N} V_i \; \frac{Ab}{b-a} \; \left(e^{-a\,(T_{end} - T_i + \Delta t)} - e^{-a\,(T_{end} - T_i)}\right)$$

$$0 = \sum_{i=1}^{N} V_i \; \frac{Aa}{a-b} \; \left(e^{-b\,(T_{end} - T_i + \Delta t)} - e^{-b\,(T_{end} - T_i)}\right),$$

where Finalpos is the final position of a component of the dynamic system, T_{end} corresponds to a time at which Finalpos is reached, A, a and b are based on the system parameters, V_i are voltage inputs to the system, T_i are the times at which V_i are input, and) t is a time interval at which V_i are input.

67. A method according to Claim 64, wherein the input determined in the determining step comprises the fundamental limiting parameter of the system, the fundamental limiting parameter corresponding to a first parameter in the system to enter into saturation.

68. A method of using a current command to control a system having voltage as a physical limiting parameter, where the system includes a current controller connected to a power supply, the method comprising the steps of:

inputting a current command to the system;

shaping the current command using a unity magnitude shaper so that the current controller in the system goes into saturation; and

supplying voltage to the system from the power supply via the current controller in saturation.

69. A method of controlling a dynamic system having one or more feedforward inputs, where one of the feedforward inputs corresponds to a fundamental limiting parameter of the system, the method comprising the steps of:

altering a form of a feedforward input that corresponds to the fundamental limiting parameter of the system so as to reduce unwanted dynamics of the system.

70. A method according to Claim 69, further comprising the step of determining the fundamental limiting parameter of the system by identifying a first parameter of the system to enter into saturation.

71. A method according to Claim 69, wherein the altering step comprises shaping the feedforward input.

72. A method according to Claim 71, wherein the shaping is performed using Input Shaping™.

73. A method according to Claim 71, wherein the shaping is performed using one or more filters.

74. A method according to Claim 71, further comprising the steps of:

identifying any nonlinear elements in the system;

wherein the shaping is performed after any nonlinear elements identified in the identifying step.

75. A method according to Claim 69, wherein the altering step comprises pre-saturating the feedforward input and then shaping the feedforward input.

76. A method according to Claim 69, wherein the dynamic system comprises a data storage device system; and

wherein the fundamental limiting parameter comprises voltage.

77. A data storage device system having one or more feedforward inputs, where one of the feedforward inputs corresponds to a fundamental limiting parameter of the system, the system comprising:

a memory which stores computer-executable process steps; and

a processor which executes the process steps stored in the memory so as to alter a form of a feedforward input that corresponds to the fundamental limiting parameter of the system so as to reduce unwanted dynamics of the system.

78. A system according to Claim 77, wherein the processor executes process steps so as to determine the fundamental limiting parameter of the system by identifying a first parameter of the system to enter into saturation.

79. A system according to Claim 77, wherein the feedforward input is altered by shaping the feedforward input.

80. A system according to Claim 79, wherein the shaping is performed using Input Shaping™.

81. A system according to Claim 79, wherein the shaping is performed using one or more filters.

82. A system according to Claim 79, wherein the processor executes process steps so as to identify any nonlinear elements in the system;

wherein the shaping is performed after any nonlinear elements identified by the processor.

83. A system according to Claim 77, wherein the processor alters the feedforward input by pre-saturating the feedforward input and then shaping the feedforward input.

84. A method of shaping an input to a dynamic system so as to reduce unwanted dynamics in the system, the input to the dynamic system comprising digital data sampled at a predetermined frequency, the method comprising the steps of:

identifying system vibrations that occur at the Nyquist frequency for the system, the system vibrations corresponding to a sine wave having two sample points per period; and

applying a three-pulse shaper to the input, wherein first and second pulses of the three-pulse shaper are applied at the two sample points in a first period of the input, and a third pulse of the three-pulse shaper is applied at a first sample point in a second period of the input.

85. A method of generating an input to a computer-controlled dynamic system so as to suppress vibrations therein, the dynamic system having a dedicated path solely for a feedforward input from a controller to controlled hardware, the method comprising the steps of:

determining a frequency of vibrations to be suppressed;

wherein, in a case that the frequency of the vibrations to be suppressed is at or below a servo rate for the dynamic system, the method comprises the steps of:

executing servo calculations for the system;

determining a servo output based on the servo calculations; and

outputting the servo output as the input to the dynamic system; and

wherein, in a case that the frequency is above the servo rate for the dynamic system, the method comprises the steps of:

determining a trajectory value;

shaping the trajectory; and

outputting the shaped trajectory as the input to the dynamic system.

86. A method of generating an input to a computer-controlled dynamic system so as to suppress vibrations therein, the dynamic system having a path by which a feedforward input and other signals are output from a controller to controlled hardware, the method comprising the steps of:

executing servo calculations for the system;

determining a servo output based on the servo calculations;

storing the servo output in a memory;

determining a trajectory value for the feedforward input;

shaping the trajectory value; and

adding the servo output stored in the memory to the shaped trajectory value so as to generate the feedforward input.

87. A method of controlling a dynamic system using an input command, comprising the steps of:

shaping the input command to saturation;

inputting the saturated command until a first predetermined condition is detected;

shaping a transition of the input command during deceleration from saturation until a second predetermined condition occurs; and

following a preset trajectory until the dynamic system comes to within a predetermined proximity of its final state.

88. A method according to Claim 87, wherein the preset trajectory comprises a curve in a PV table.

89. A method of generating commands for a dynamic system in a first parameter which maintain a limit in a second parameter, where the second parameter

comprises a fundamental limiting parameter of the dynamic system, the method comprising the steps of:

determining a response of the second parameter in the dynamic system to a unit command in the first parameter; and

generating the command in the second parameter based on the response determined in the determining step.

90. A method according to Claim 89, wherein the first parameter is current and the second parameter is voltage; and

wherein the dynamic system comprises a disk drive.

91. A method according to Claim 89, wherein the response is determined by iteratively solving a set of equations for the first parameter knowing at least the second parameter.

92. A method according to Claim 91, wherein the set of equations comprises:

$$\sum_{i=1}^{N} A_i = 0,$$

where A comprises amplitudes of the command in the first parameter at each time interval i, and N comprises a last time interval;

$$v_i = C_{vscale} \sum_{j=1}^{i-1} A_i,$$

where v comprises a system velocity and C_{vscale} is a constant;

$$P_{final} = \sum_{j=1}^{N} v_i \,,$$

where P_{final} comprises a final state of the system; and

$$-V_{\lim} < \sum_{i=1}^{J} A_{j-i+1} \; R_i < V_{\lim}\,, \;\; j = 1 \rightarrow N\,,$$

where R comprises a pulse response of the system to the second parameter and $V_{\lim}$ comprises a limit in the second parameter.

93. A method according to Claim 92, wherein A comprises current, V comprises voltage, and R comprises a voltage response of the system.

94. A method according to Claim 92, wherein the values of R(i) are determined by taking a peak value of the system response and sampling values of the system response at subsequent time increments.

95. A method generating commands for a dynamic system in a first parameter (A) which maintain a limit in a second parameter (V), where the second parameter (V) comprises a fundamental limiting parameter of the dynamic system, the method comprising the steps of:

determining a values for a command in the first parameter (A) at time intervals (i) based on the following relationship:

$$A(i) = \frac{V_{\max} - \sum_{j=2}^{i} A(i+1-j)\ R(j)}{R(1)},$$

where R comprises a pulse response of the system in the second parameter; and

formulating a command over time in the first parameter (A) based on the A(i) values determined in the determining step.

96. A method according to Claim 95, wherein A comprises current and V comprises voltage.

97. A method of controlling a dynamic system having vibrations resulting from movement, the method comprising the steps of:

identifying transitions of an input command to the dynamic system; and

shaping transitions of the input command so as to result in a system response to the input command with reduced vibrations.

98. A method of controlling a system to reduce unwanted dynamics using commands in both first and second parameters, where the second parameter comprises a fundamental limiting parameter of the system, the method comprising:

commanding the system in the first parameter during a first mode of system operation; and

commanding the system in the second parameter during a second mode of system operation.

99. A method according to Claim 98, wherein the system comprises a disk drive;

wherein the first mode of operation comprises tracking performed by the disk drive; and

wherein the second mode of operation comprises seeking performed by the disk drive.

100. A method according to Claim 92, 94, and 95, wherein V_{lim} is varied in accordance with i.

101. A method according to Claims 89 to 95, wherein constraints are added for parameter slew rate limits; and

wherein the generating step generates the command in accordance with the added constraints.

102. A method of rescaling a vibration-limiting input to a dynamic system, the method comprising the step of:

linearly scaling amplitudes of the vibration-limiting input to produce a scaled vibration-limiting input.